

CHARACTERIZATION OF SHORT
PINEAPPLE LEAF FIBER REINFORCED
TAPIOCA BIOPOLYMER COMPOSITES

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Doctor of Philosophy

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ABSTRAK

Pembangunan bahan mesra alam seperti komposit serat semulajadi semakin mendapat perhatian dalam beberapa tahun kebelakangan ini disebabkan oleh peningkatan kesedaran terhadap alam sekitar berhubung dengan pelbagai kesan buruk yang telah dihasilkan oleh polimer berasaskan petroleum. Di antara kesemua serat semulajadi, serat daun nanas (PALF) mempunyai potensi besar sebagai agen pengukuhan komposit kerana kosnya yang rendah, ketersediaan yang tinggi, kandungan selulosa yang tinggi dan sifat mekanik yang relatifnya lebih tinggi berbanding dengan serat semulajadi yang lain. Dalam kebanyakan penyelidikan terdahulu, PALF digunakan sebagai penguat dalam polimer berasaskan petroleum yang tidak terbiodegradasi bagi menghasilkan komposit serat semulajadi. Walau bagaimanapun, inovasi polimer berasaskan kanji yang dipanggil biopolimer ubi kayu (TBP) menyediakan alternatif sebagai matriks biodegradasi untuk pembangunan komposit mesra alam. Oleh itu, gabungan PALF dan TBP dalam pembangunan komposit bio kelihatan seimbang antara perspektif ekologi dan ekonomi. Sebagai gabungan baru, penyelidikan ini dijalankan untuk menentukan parameter gabungan optimum komposit PALF-TBP dalam menghasilkan sifat mekanik yang kompetitif. Terdapat empat pertimbangan penting dalam pembuatan komposit dalam menghasilkan sifat mekanik yang tinggi seperti suhu pemprosesan yang digunakan dalam proses pembuatan, panjang serat, peratusan kandungan serat dan rawatan yang terlibat. Kerja eksperimen bermula dengan proses pencirian bahan TBP dan PALF. Selepas itu, penyediaan sampel yang dijalankan terdiri daripada proses menghancurkan serat dan pengasingan, proses pencampuran dalaman, pengacuan mampatan dan proses pemesinan. Sampel TBP dengan suhu pemprosesan yang berbeza (160°C, 165°C, 170°C, 175°C, 180°C dan 185°C) disediakan untuk menentukan suhu pemprosesan optimum TBP. Selain itu, sampel komposit dengan panjang serat yang berbeza (≤ 0.50 mm, 0.51-1.00 mm dan 1.01-2.00 mm) dan kandungan serat yang berbeza (10%, 20%, 30% dan 40%) disediakan untuk menilai kesan variasi panjang serat dan peratusan serat pada sifat mekanikal komposit PALF-TBP. Selain itu, tiga rawatan yang berbeza telah dipilih iaitu compatibilizer maleic anhydride polypropylene (MAPP), compatibilizer maleic anhydride polietilena (MAPE) dan rawatan alkali untuk penyiasatan kesan rawatan terhadap sifat tegangan komposit PALF-TBP. Analisis untuk menentukan keseluruhan objektif penyelidikan terdiri daripada analisis sifat terma, dan analisis sifat mekanik. Di samping itu, pemeriksaan mikroskop elektron (SEM) telah dijalankan sebagai pengesahan keputusan. Hasil kajian mendapati bahawa suhu pemprosesan optimum untuk TBP adalah 165°C hingga 170°C dan kombinasi terbaik untuk pembangunan komposit TBP yang diperkuatkan oleh PALF pendek adalah yang dihasilkan oleh pengacuan mampatan yang terdiri daripada 30% kandungan serat dan 7% kandungan agen gandingan MAPP. Walau bagaimanapun, pengaruh pelbagai panjang serat sehingga 2.00 mm tidak memberikan pengaruh yang signifikan ke atas menghasilkan sifat tegangan maksimum. Penemuan ini menunjukkan bahawa gabungan PALF dan TBP yang pendek mempunyai potensi besar sebagai komposit mesra alam untuk menjadi alternatif kepada polimer konvensional dalam aplikasi kejuruteraan terutamanya dalam sektor automotif. Peningkatan pembangunan komposit PALF-TBP pada masa akan datang seperti penggunaan PALF dengan kekuatan tegangan yang lebih tinggi yang diharapkan mampu meningkatkan dan memperbaiki hasil yang ada sekarang.

ABSTRACT

The development of environmental friendly material, such as natural fiber composites, has been getting more attention in recent years due to increase in environmental awareness of various adverse petroleum-based polymer effects. Among all natural fibers, pineapple leaf fiber (PALF) has great potential as a reinforcement agent because it is low cost, highly available with high cellulose content, and has relatively higher mechanical properties as compared to other natural fibers. Most previous research works had used PALF as reinforcement in non-biodegradable petroleum-based polymers to produce natural fiber composites. However, the starch-based polymer innovation, called tapioca biopolymer (TBP), provides an alternative for biodegradable matrix for the development of environmental friendly composites. Therefore, the combination of PALF and TBP in bio-composites development appears to be a perfect balance between the ecology and economic perspectives. As a new combination, this research was conducted to determine the optimum PALF-TBP composites combination parameters to produce competitive mechanical properties. To produce high mechanical properties, there are four essential considerations in the preparation of composites, such as the manufacturing process temperature, fiber length, fiber composition and treatment involved. The experimental work began with material characterization of TBP and PALF. Then, sample preparation was conducted, which consisted of fiber crushing and sieving, internal mixing, hot press and machining. TBP samples at different processing temperatures (160°C, 165°C, 170°C, 175°C, 180°C and 185°C) were prepared to determine the optimum processing temperature. Also, composite samples with different fiber lengths (0.10-0.50 mm, 0.51-1.00 mm and 1.01-2.00 mm) and different fiber loadings (10%, 20%, 30% and 40%) were prepared to evaluate the effect of varying fiber lengths and fiber loadings on mechanical properties of PALF-TBP composites. On the other hand, three different treatments were selected, which were maleic anhydride polypropylene (MAPP) compatibilizer, maleic anhydride polyethylene (MAPE) compatibilizer and alkali treatment for investigating the treatment effect on tensile properties of PALF-TBP composites. The analyses to determine the entire research objective consisted of thermal properties analysis and mechanical properties analysis. In addition, the scanning electron microscopy (SEM) analysis was carried out for result validation. Test results established that the optimum processing temperatures for TBP are 165°C to 170°C with the best combination for the development of short PALF reinforced TBP composite was produced by a hot press process, comprising 30% fiber loading and 7% MAPP coupling agent. However, the influence of various fiber lengths of up to 2.00 mm provided no significant influence on the production of maximum tensile properties. The finding demonstrated that the combination of short PALF and TBP had great potential as environmental friendly composites to be an alternative for the conventional polymers in engineering applications, especially in the automotive sector. Improvement of future PALF-TBP composites development, such as the utilization of PALF with higher tensile strength, is expected to be capable of enhancing and improving the present result.

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LIST OF SYMBOLS

α	Alpha
β	Beta
cm	Centimeter
$^{\circ}\text{C}$	Degree Celsius
E	Margin of error for statistical application
E	Chord modulus
ε	Strain value
GPa	Giga Pascal
g	Gram
h	Hour
J	Joule
kJ	Kilo Joule
kN	Kilo Newton
m	Meter
min	Minutes
ml	Mililiter
MPa	Mega Pascal
M_a	Weight of air-dried sample
M_c	Weight of crucible
M_{cl}	Weight of crucible containing lignin content
M_o	Weight of oven-dried sample
N	Newton
n	Sample size
n_1	Sample size for group 1
n_2	Sample size for group 2
$^{\circ}$	Degree
σ	Stress value
σ_f	Tensile strength of natural fiber
σ_m	Tensile strength of matrix
S	Standard deviation
S_1	Standard deviation for group 1
S_2	Standard deviation for group 2
v	Degree of freedom for statistical application
v_f	Composition of fiber
v_m	Composition of matrix

w/v	Weight per volume
\bar{x}	Mean
\bar{x}_1	Mean for population group 1
\bar{x}_2	Mean for population group 2
γ	Gamma
%	Percent

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
ATR	Attenuated Total Reflectance
CMC	Ceramic Matrix Composites
CNC	Computer Numerical Control
DSC	Differential Scanning Calorimetry
FL	Fiber Length
FTIR	Fourier Transform Infrared Spectroscopy
HDPE	High-Density Polyethylene
ICBP	Indochine Bio Plastiques
IUPAC	International Union of Pure and Applied Chemistry
LDPE	Low-Density Polyethylene
MAPE	Maleic Anhydride Polyethylene
MAPP	Maleic Anhydride Polypropylene
MMC	Metal Matrix Composite
NaOH	Sodium Hydroxide
PALF	Pineapple Leaf Fiber
PBS	Poly (Butylene Succinate)
PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene Terephthalate
PLA	Polylactic Acid
PMC	Polymer Matrix Composites
PP	Polypropylene
PU	Polyurethane
PVC	Polyvinylchloride
SEM	Scanning Electron Microscopy
TAPPI	Technical Association of the Pulp and Paper Industry
TBP	Tapioca Biopolymer
TGA	Thermogravimetric Analysis
UNFCC	United Nations Framework Convention on Climate Change

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